Mariner Mars 1971 Orbiter Propulsion Subsystem Type Approval Test Program

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A new propulsion subsystem was used on the *Mariner* Mars 1971 orbiter spacecraft to provide the necessary impulse for trajectory corrections, Mars orbit insertion, and Mars orbit trim maneuvers. The type approval test program that provided the functional, structural, and environmental qualification of this subsystem and demonstrated its performance margin in excess of flight mission requirements is described. A brief discussion of the problems encountered is included.

Introduction

The *Mariner* Mars 1971 spacecraft is designed to use the basic vehicle employed on previous *Mariner* (fly-by) missions with the incorporation of a new and larger propulsion subsystem (Figure 1) to decelerate the spacecraft from a hyperbolic approach trajectory and place it into an elliptical orbit about Mars. The schematic diagram of this pressure-fed, bipropellant subsystem is shown in Figure 2. A regulated supply of filtered nitrogen gas is used to expel the hypergolic fuel (monomethylhydrazine) and oxidizer (nitrogen tetroxide), each of which is contained in a Teflon expulsion bladder, from the propellant tanks through a filter to the rocket engine. Braided, Teflon-lined, flexible hoses are used to permit gimballing of the rocket engine to provide spacecraft pitch–yaw control. Positive isolation of the pressurant and propellants is achieved with explosively actuated gate valves, which are actuated by ground commands.

Because this propulsion subsystem was new and different from those previously used, it was required that it be subjected to a type approval (TA) test program. Successful completion of this test program would then qualify the subsystem for the 9-mo mission for which it was designed.

Components identical to those used on the flight spacecraft were employed in the assembly of the propulsion subsystem to be used for

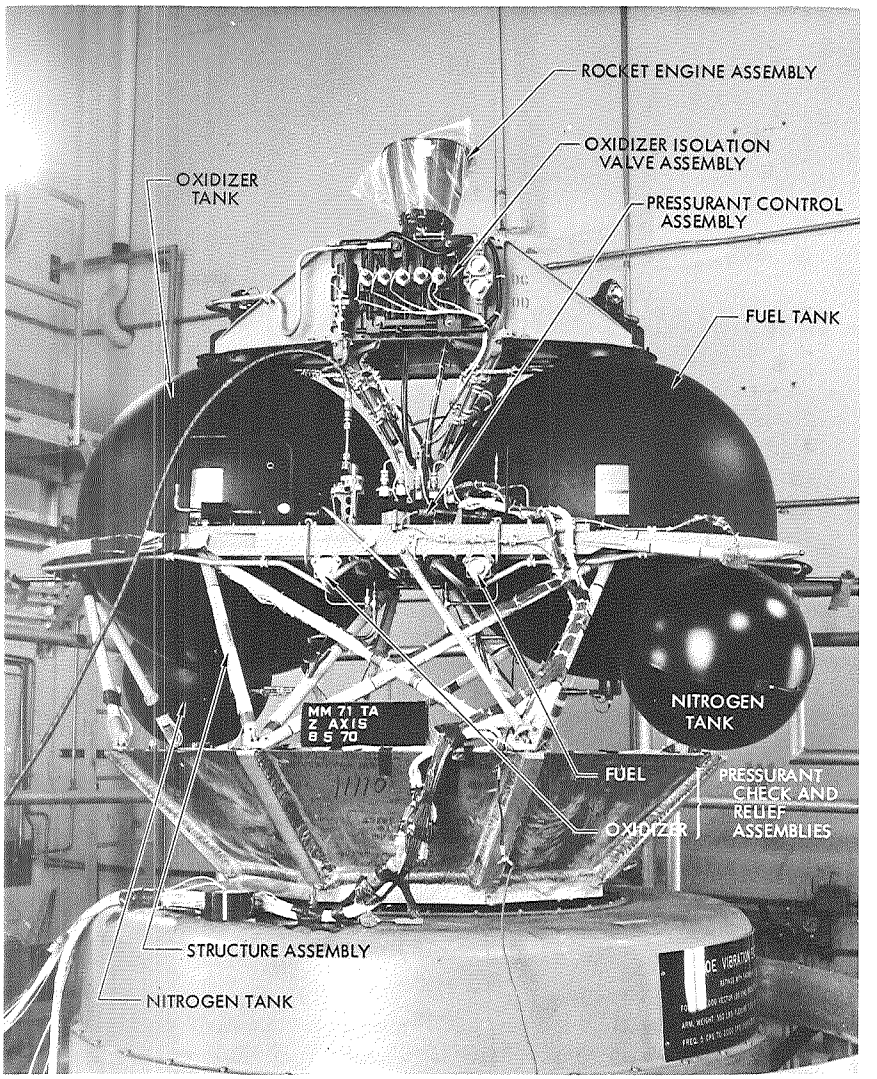

Figure 1. Fueled and pressurized TA propulsion subsystem ready for vibration

the type approval test program. After assembly this test subsystem was subjected to the same flight acceptance tests to which the flight subsystems were exposed.

The TA test program was conceived and conducted to demonstrate functional and structural margin and performance capability in excess of that which will be required of those subsystems to be used for the flight mission. To this end the test conditions listed below were planned.

(1) Higher level and increased duration for mechanical vibration.

(2) Operation at extreme temperature limits.

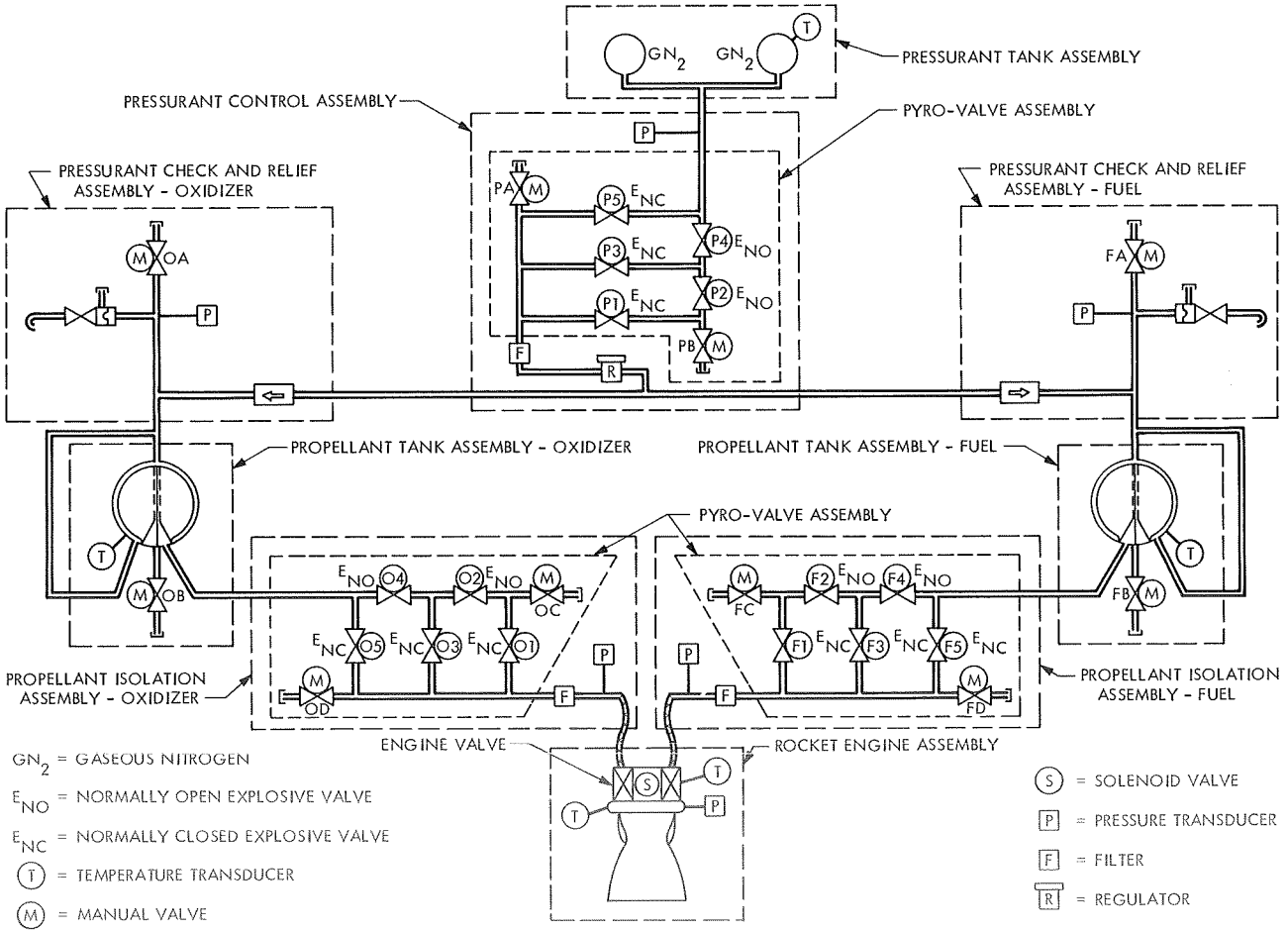
PRESSURANT TANK ASSEMBLY
PRESSURANT CONTROL ASSEMBLY
PYRO-VALVE ASSEMBLY
PRESSURANT CHECK AND RELIEF ASSEMBLY - OXIDIZER
PRESSURANT CHECK AND RELIEF ASSEMBLY - FUEL
PROPELLANT TANK ASSEMBLY - OXIDIZER
PROPELLANT TANK ASSEMBLY - FUEL
PYRO-VALVE ASSEMBLY
PROPELLANT ISOLATION ASSEMBLY - OXIDIZER
PROPELLANT ISOLATION ASSEMBLY - FUEL
ENGINE VALVE
ROCKET ENGINE ASSEMBLY
GN2 = GASEOUS NITROGEN
ENO = NORMALLY OPEN EXPLOSIVE VALVE
ENC = NORMALLY CLOSED EXPLOSIVE VALVE
T = TEMPERATURE TRANSDUCER
M = MANUAL VALVE
S = SOLENOID VALVE
P = PRESSURE TRANSDUCER
F = FILTER
R = REGULATOR

Figure 2. Schematic of *Mariner* Mars 1971 propulsion subsystem

(3) Two-mission duty cycles.

(4) Extra handling and servicing.

(5) Additional functional and component checks.

(6) Other extended operating limits, such as high tank pressures, extreme non-operating temperatures, and extreme engine valve temperatures prior to firing.

Description of Events

The sequence of the TA program was as listed below.

(1) Component acceptance tests.

(2) Flight acceptance tests of subassemblies, conducted to verify proof of workmanship, quality, and performance characteristics of the subassemblies.

(3) Flight acceptance tests of the propulsion subsystem, which included the tests listed below.

  (a) Subsystem fabrication and assembly.

  (b) Proof pressure test.

  (c) External leakage test.

  (d) Functional test (regulator, valves).

  (e) Vibration test, loaded with solvents to simulate propellant mass.

  (f) Acoustic test, simulating launch environment.

  (g) Bladder leakage test.

  (h) External leakage test.

  (i) Functional test.

  (j) External leakage test.

The above tests were the same as those that all flight subsystems experienced prior to the actual mission. Then, to simulate mission conditions, Test Series 1 and 2, as outlined in Tables 1 and 2, were performed.

Test Series 1 and 2 simulated two-mission duty cycles. The fact that the pyro valves were irreversible in operation precluded a complete simulation, so the sequences were folded, as shown in Tables 1 and 2. The total engine firing time of each test series exceeded that expected for flight. Therefore, the engine, filters, bladders, and service valves demonstrated margin in capacity and cycle capability. The extra handling and servicing required for two propellant loadings and unloadings

Table 1. Test Series 1 (high temperature)

Test sequence	Simulated mission sequence
1. Propellant vibration (3 axes)	Launch
2. Installation in vacuum chamber	2-wk coast
3. Open and close engine valve	Liquid line vent
4. Pyro valves open (-1 series)	Pyro valves open (-1 series)
5. 8-s firing	Midcourse 1 firing
6. 1-day hold	1-wk coast
7. Pyro valves close (-2 series)	Pyro valves close (-2 series)
8. 1-day hold	6-mo coast
9. Pyro valves open (-3 series)	Pyro valves open (-3 series)
10. 10-s firing	Midcourse 2 firing
11. 1-day hold	20-day coast
12. 900-s firing	Orbit insertion firing
13. 2-day hold	2- to 4-day coast
14. 0.4-s firing	Orbit trim 1 firing
15. 3-day hold	2- to 4-day coast
16. 40-s firing	Orbit trim 2 firing
17. Not performed	Coast Pyro valves close Orbit planet

qualified the techniques and subsystem in the case of offloading propellants for repairs prior to launch. The engine was heated to 338.7 K (150°F)[1] prior to the first midcourse firing, approximately 11 K (20°F) hotter than that predicted from solar radiation; the subsystem was heated to 303.7 K (87°F), near the maximum of its specified range [305.4 K (90°F)] and 6.7 K (12°F) warmer than that predicted for the first midcourse maneuver. Cold propellants were then loaded for Test Series 2, and the propellants were at 280.3 K (45°F) at the time of the orbit insertion firing, compared to an expected temperature of 297 K (75°F). These temperature extremes were intended to demonstrate margin for bladder collapsing, engine valve operation, check valve operation, and the operation of other temperature-sensitive components. Saturated propellants were not used for testing, since analysis had shown that the predicted level of saturation at the time of orbit insertion would be well

[1]Values in customary units are included in parentheses after values in SI (International System) units if the customary units were used in the measurements or calculations.

Table 2. Test Series 2 (low temperature)

Test sequence	Predicted mission sequence
1. Not performed	Launch through midcourse 2 firing
2. 900-s firing	Orbit insertion firing
3. 3-day hold	2- to 4-day coast
4. 16-s firing	Orbit trim 1 firing
5. 1-day hold	2- to 4-day coast
6. Not performed	Orbit trim firing / Coast
7. Pyro valves close (-4 series)	Pyro valves close (-4 series)
8. 1-day coast	Orbit planet
(End of nominal sequence)	
9. Pyro valves open (-5 series)	Margin demonstration operations
10. 10-s firing	
11. 1-day coast	
12. 20-s firing	

below the threshold required to affect performance. The orbit insertion firing of Test Series 2 was performed with propellant tank pressures initially 17 N/cm^2 (25 psi) higher than expected, simulating tank heating or regulator gas leakage.

Results and Conclusions

Two problem areas were discovered in the subsystem TA program. A beryllium tube supporting one of the pressurant tanks failed during vibration with solvents. This occurred at the resonant frequency of the pressurant tanks, and was due to a higher than expected tank response. The pressurant tank support tubes were replaced with steel tubes and were qualified. The oxidizer check valve partially opened during the first engine firing of Test Series 1, and the oxidizer tank supplied propellant in a blowdown mode. Operation for later engine firings was satisfactory. A detailed component test program determined the cause of the check valve sticking to be interference between the Teflon poppet and the metal poppet guide, due to oxidizer absorption and thermal growth of the poppet. Predicted temperatures during the actual mission are 19.3 K (35°F) lower than the check valve temperature at the time of the observed sticking. This, combined with the fact that momentary sticking would have little possibility of degrading the mission, resulted in the decision to not change the flight check valves.

All other components functioned as expected. All specification requirements were satisfied. Reliability of the propulsion subsystem was demonstrated and all interfacing equipment, such as pyro, thermal, structure, and support equipment, operated and functionally interfaced satisfactorily.